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SIMULATOR TRAINING EFFECTIVENESS AS A FUNCTION OF ERROR COUNTS ON THE F-15A FLIGHT SIMULATOR INSTRUCTOR OPERATOR STATION

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NOTICE

This final report was submitted by Flying Training Division, Air Force Human Resources Laboratory, Williams Air Force Base, Arizona 85224, under project 1123, with HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235. Dr. William H. Nelson (FTO) was the Principal Investigator for the Laboratory.

This technical report has been reviewed and is approved for publication.

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Effective simulator training is an important factor in the Air Force's overall ability to train pilots. A major problem is that simulator managers tend to assume that their machines are always optimally designed and used. In addition, investigators find it difficult to evaluate simulator training in quantitative terms while working in an operational setting. These problems reflect the need for the Air Force to carefully consider current and future simulator designs and training programs. This study was designed to investigate procedural errors made at the F-15A Simulator Instructor/Operator Station (IOS) by instructor pilots (IPs). An observer recorded the number of errors and the time needed to correct each error during a typical 90-minute session. Questionnaires were filled out by 34 F-15 aircraft IPs and 16 F-15 simulator operators indicating their respective simulator experience. Data were

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collected during actual training missions to determine if IP errors seriously detracted from training time. The results showed that the average number of errors and average error time had an insignificant impact on simulator training. The number of simulator sessions flown by each IP in the course of the present study was identified as an important factor in effective simulator training, varying inversely with error counts. However, no relationship was found between total IP hours and average error count. In addition, the electronic tactics selected by the IP may have had an effect on average error count. Additional research is needed to determine if IOS modification will increase simulator training effectiveness.

PREFACE

This study was conducted as an outgrowth of Tactical Air Command (TAC), Project 75A-034H Operational Test and Evaluation (OT&E) of the F-15A Flight Simulator. This report covers research conducted during July and August 1978.

This research was conducted by Cadet John Micalizzi of the United States Air Force Academy sponsored by Frank J. Seiler Research Laboratory, as a summer research project under the direction of Dr. William Nelson, Air Force Human Resources Laboratory (AFHRL/FTO) at Luke AFB.

Special appreciation is expressed to the research support personnel at Luke AFB for their assistance; TAWC/OLAH, commanded by Col Ray F. McNally for their support; the airmen and non-commissioned officers of the 58th Component Repair Squadron for their assistance and professionalism and to Mr. Robert Coward, Senior Research Psychologist, AFHRL/FTO for his guidance and assistance throughout this project.

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Background and Purpose

Flight simulation is not a recent innovation in pilot training. Dorsey (1976) reported that simulators, or trainers, have been available for years for such diverse mechanisms as ships, trains, automobiles, orbiting vehicles, advanced radar, and airplanes. However, the evolution of flight simulation from the complex, mechanical devices of World War II vintage, to the digital computer-generated simulated tactics and targets of today, is impressive.

Air Force use of flight simulators is increasing. Various factors such as improved simulator technology, increased costs of operating aircraft, fuel costs and scarcity, environmental effects of aircraft operations, and safety reasons are causing the Air Force to increasingly depend upon simulator training to help keep personnel combat ready (Caro, 1977a). Simulator use is expected to increase and, as a function of increased training capability, provide better training.

With increased simulator use requirements, effective design and implementation of simulator training programs must be considered. Simulator training managers tend to assume that simulators are always optimally designed and used (Caro, 1977b). However, extensive use does not insure efficient training. In one study, for example, it was found that the extensive use of a particular device added cost, but no training value, to an already expensive pilot training program (Isley, Caro, & Jolley, 1968). This finding was largely attributed to the less-than-optimal design of that particular device (Caro, 1970). There are few studies which evaluate simulator training in quantitative terms. Most are based upon subjective opinion rather than objective data. Burger and Brictson (1976) reported that systematic, controlled studies with simulators may interfere with operational training schedules, and cognizant personnel may lack the time and resources necessary to conduct such investigations. In addition, quantitative and measurable performance criteria have not yet been established. So the simulator researcher is faced with the difficulty of implementing a classical experimental design within an operational setting.

Charles, Willard, and Healey (1975) revealed that lack of effective training existed for instructor pilots (IPs) and simulator operators (SOs) in both simulator operation and utilization, and in "how to instruct." Therefore, simulator training was not well employed, standardized, or in general, appreciated by IPs. The role of the IP was found to vary within the system in terms of crew size and pilot task, with the role of the SO depending on the establishment of the IP role. In addition, the proliferation of displays and controls on the instructor/operator station (IOS) may be detrimental to effective training.

Muckler, Nygaard, O'Kelly, and Williams (1959) reported that many studies compound the impact of such potential influences as training program content, instructional technique, and instructor qualification into a single independent variable. Realized benefits, then, can be attributed only to the unique combination of those influences. Generalizations, however, must be cautious since these studies are seldom replicated and may address unique training requirements.

Some factors which may influence simulator training effectiveness include visual fidelity, motion fidelity, trainee and instructor characteristics, attitudes and expectations, among others. Simulator managers must include these factors in the overall evaluation of simulator training. Unawareness of such influences may result in inadequate development of critical skills, unnecessary use of aircraft, excessive training costs, and inefficient simulator training. Effective simulator training is critical if the Air Force is to comply with the Department of Defense goal of significant reduction in aircraft use for flight training by 1981, while still maintaining the present quality of that training (U.S. Government Printing Office, Note 1).

The F-15A flight simulator (FS), designed and manufactured by Goodyear Aerospace Corporation (Note 2), represents a new generation of advanced digital and simulation engineering technology. This simulator accurately depicts the operational performance characteristics of the F-15A aircraft and creates a controlled, tactical environment where the student can learn to use the F-15A weapons system.

In a recent Operational Test and Evaluation (OT&E) of the F-15A FS Instructor Operator Station (IOS), several training deficiencies were noted. The purpose of the OT&E was to consolidate findings of testing and operational use and initiate modifications to make the F-15 FS more effective and efficient. As part of the evaluation, the Air Force Human Resources Laboratory (AFHRL) sponsored a Human Factors Test and Evaluation (HFT&E) of the F-15A FS IOS.

The IOS represents the man-machine interface for the F-15A simulator. The cathode ray tubes (CRTs) of the IOS present radar information, heads-up display (HUD) information, and a three-dimensional view of the tactical environment including the F-15A and adversaries. This three-dimensional view of the emitter targets (ETs) environment is a complex display controlled by the right-hand console control board. The display subpanel is used in conjunction with the keyboard to call up selected display pages and to control malfunctions and intercept display content. The tactics subpanel is also used with the keyboard to position the FS and to select, activate, and control ETs. This interaction is very complex and requires multiple button-selection sequencing. Baer and Sanders (1977) found that an average of 22 button pushes were needed to select a radiating target, enter a bearing and range, activate, and take manual control. To reinitiate the mission, an average of 19 button pushes were required. The HFT&E team compared their findings with the problems discussed in the interim IOS report (Baer, 1977). Both studies (Baer, 1977; Crites, 1977) reported excessive button pushing and consequential errors on the tactics board (right control panel). The HFT&E also revealed that IP training was insufficient, resulting in trial and error learning at the IOS. Frustrated IPs would often opt to take manual control of the airborne ETs rather than set up the more difficult preprogrammed typical missions. Training appeared to suffer when the IOS automatic capabilities were not used. As a result, TAC has asked the F-15A Operations Training Development Team (OTD) to develop a simulator operator's handbook geared for the line pilot/instructor. This handbook will address the pilot interface with the SO who, in most cases, will be the actual console operator. A course of instruction in the operation of the F-15A FS IOS has been generated for new IPs at Luke AFB. It includes 1 1/2 hours of classroom instruction by an SO and 1 1/2 hours at the IOS with an SO and a qualified IP. A clearly written basic IOS operators handbook has been generated, and an IP has been assigned full-time to develop more preprogrammed missions.

In view of findings during the HFT&E and subsequent actions by the training agencies, AFHRL/FT undertook an effort to look independently into the problem of F-15A FS IOS operation. Some important questions remained unanswered (e.g., Are the error counts significant enough to consider redesigning the tactics console? Do error corrections seriously detract from simulator training? Why do some IPs make less errors than others?). This preliminary investigation into such questions utilized data from direct observation of daily simulator operations. The average number of errors, the average error time, and the average actual training time were computed. In addition, IP average error and electronic tactics use were also investigated. The results of this study were compared to those made in August 1977 during the AFHRL Sponsored IOS design study.

II. METHOD

In April 1977, TAC began an operational test and evaluation (OT&E) of the F-15A FS, built by Goodyear Aerospace Division and located at Luke AFB. Air Force Human Resources Laboratory, Flying Training Division, Tactical Training Research Branch (AFHRL/FTO) at Luke AFB, was asked to assist in the conduct of the operational evaluation of the F-15A FS in several areas. This report is an outgrowth of the findings from one of the areas investigated.

Design

A direct observation study of daily simulator operations was the general research design. The investigator collected data in the F-15A FS #1 located at Luke AFB between 6 July and 3 August 1978.

During the study, the simulator was operating continuously from 0600 hours to 1800 hours. Monday through Friday. Each day's schedule was divided into eight, 90-minute sessions. As students progressed through the flight syllabus, they were assigned specific simulator sessions at various stages of their training. As such, scheduling of simulator sessions was dictated by operational commitments. A further complication was computer downtime (about 10% of the sessions).

The investigator monitored three sessions per day at 0900, 1030, and 1330 hours. During monitored sessions, the investigator recorded the number of errors made by the IPs at the tactics board, the time taken to correct errors, and total training time. During unmonitored sessions, the SO tallied the number of errors made by the IP.

Any subjective information about simulator operating procedures was recorded by the investigator for later use in answering some difficult questions on simulator training effectiveness.

Subjects

The subjects consisted of 34 instructor pilots qualified in the F-15A aircraft. Their ranks ranged from First Lieutenant through Major. IP experience in the F-15A FS varied greatly, ranging from 0 to 200 hours.

Sixteen SOs were also present in the study. They seldom operated the IOS but they were available to answer questions and to help with specific problems. Experience ranged from 4 months to 19 months on the F-15A IOS.

Apparatus

Counter. A Systron-Donner Model 6152A digital counter was set to trigger (count) once for each illumination of the ERROR light on the tactics console. It was installed in the computer input/output cabinet and was not visible to the IP.

IP Questionnaire. IPs recorded their flying experience, including type of aircraft, total hours, and IP hours in each type, and simulator experience, including type of simulator, total hours, and IP hours in each type (see Table 1 and Appendix A).

Table 1. **Hours of Simulator Experience of Instructor Pilots by Simulator Type and Number of Instructor Pilots**

	Simulator Type			
	F-4	F-15	T-38	A-7
Total hours of experience[a]	2,500	1,875	500	250
Number of IPs	11	20	2	1

[a]Rounded to nearest 25 hours increment.

SO Questionnaire. Individuals recorded experience as operator and/or technician on the F-15A FS IOS or any additional simulator (see Table 2 and Appendix B).

Table 2. **Months of Simulator Experience of Simulator Operators by Simulator Type and Number of Operators**

	Simulator Type									
	F-15	F-4E	A-7D	SAAC	C-11-C	F-4D	F-100	F-111A	FB-111A	F-105D
Total months of experience	175	142	73	49	45	42	36	17	17	5
Number of operators	15	8	3	4	1	3	1	1	1	1

F-15A IOS Evaluation Worksheet. The SO recorded the date, simulator number, course number, names of the SO, IP, and student, whether the session was completed, the ET set number, the number of errors, and the scheduled session time. The investigator recorded errors, error time, and total training time during monitored sessions (see Appendix C).

Stop watches. One stopwatch was used to record total training time. Another stopwatch was used to record error time only.

Procedure

During unmonitored sessions (0600, 0730, 1200, 1500, and 1630 sessions) the SO filled out the worksheet and recorded the number of errors displayed on the counter.

During monitored sessions (0900, 1030, and 1300 sessions) the SO filled out the worksheet and the investigator recorded the number of errors, error time, and total training time. The total training time stopwatch was started when both the IP and student were seated and voice communication was established. It was stopped when the student removed the headset and climbed from the cockpit.

The error time stopwatch was started when the error light was activated and was stopped when the IP completed entry of the correct information.

The investigator also made visual tallies of errors to confirm the number displayed on the counter. In addition, the investigator talked on an informal basis with IPs and SOs and made note of any special circumstances in the daily operation of the simulator for future use.

III. RESULTS

The results of the evaluation are presented and discussed according to three topical areas: (a) Session Results, (b) IP Results, and (c) Electronic Tactics Results.

Session Results

During 35 monitored sessions (52.5 hours) the average error time per session was 53 seconds or approximately 1% of the scheduled 90 minutes ($\sigma \approx 82$). Each session is comprised of from one to several varied mission events depending on the syllabus. Actual training time was defined as total training time minus error time. During monitored sessions, the average actual training time per session was 76 minutes or 84% of the scheduled 90 minutes ($\sigma \approx 11$). Seven errors per session, on the average, were committed by IPs for 107 total sessions, including monitored and unmonitored sessions ($\sigma \approx 9$).

IP Results

IPs in the earlier IOS design study committed an average of nine errors per session ($\sigma \approx 8$). For those with three or more sessions, the average dropped to seven errors per session ($\sigma \approx 5$). The average dropped further to five errors per session for those IPs in the present study who were also in last year's study ($\sigma \approx$

5). For IPs in the present study only, the error count was back up to seven errors per session (σ = 7). The Pearson Product Moment Correlation Coefficient was applied to determine the relationship between the number of sessions and the average error count for each IP (Roscoe, 1975).

For IPs in the 1977 IOS design study, r = -.32, (p = .059). For IPs in the 1978 study who were also in last year's study, r = -.62, (p = .00047). The difference between the two correlation coefficients was significant at the .0951 level.

The Pearson Product Moment Correlation Coefficient was also calculated for IP hours on the F-15A FS versus the average error count. The value of the coefficient (r = .022) indicates no significant relationship between IP hours on the simulator and average error count.

Electronic Tactics Results

The electronic tactics results indicated that ETs are being used in about 25% of the sessions. Syllabus requirements dictate that certain sessions are to be flown without ETs but many IPs opt to use manual targets (30% of the sessions) where they are in control and can back up or accelerate training according to the individual student's progression. However, both manual targets and ET sets are responsible for high average error counts (11 and 10 errors per session, see Table 3).

Table 3. **Electronic Tactics Results**

Target Mode	Average Errors Per Session	% of Sessions
Manual Targets and ETs Not Used	2	45
ETs Used	10	25
Manual Targets Used	11	30

Although the averages indicate rather small error counts and times, there was a wide range of variation among IPs. Error counts range from 0 to 53, and some IPs spent over 5 minutes just correcting errors. These are important deviations which may be a function of experience and motivation.

IV. DISCUSSION AND RECOMMENDATIONS

The present IOS design study was a preliminary investigation into the error counts and training effectiveness of the F-15A FS IOS and will serve as a follow up to the earlier study. This study attempted to identify specific problems and indicate directions for additional research.

The error time and counts may not be as important as was previously thought. There was an average of seven errors per session committed at the IOS. Average error time was 53 seconds per session (1% of scheduled training time). However, there were only 76 minutes (84%) on the average, of actual training time contained in one 90-minute session. About 15% of the scheduled session time was lost due to computer malfunction, or delayed start. Additionally, errors in the present study did not seriously detract from training time since an average of only 8 seconds was required to correct an error. Training is a continuous process, and although an IP commits an error at the IOS, the student is still flying and receiving training while the error is being corrected.

IPs did report excessive button pushing for even the simplest maneuvers; however, IP performance improved with practice. IPs in the earlier design study committed an average of nine errors per session, but for those with three or more sessions the average error count dropped to seven errors per session. Among IPs in the present study who were also in the earlier study, the error count dropped further to five errors

per session while, for those IPs in the present study only, the average count returned to seven errors per session.

Utilizing only those pilots common to both studies, the correlation between number of sessions and average error count in the present study was higher than before (see Figures 1 & 2). As the number of sessions increased, the average error count tended to decrease. However, there were no statistically significant relationships between total IP hours on the simulator and average error count. This result may be explained by considering that the more experienced IPs preferred to stumble through the complicated switchology of the F-15A FS rather than ask the operator for assistance. Less experienced IPs asked for assistance sooner and more often. Consequently, more experienced IPs tended to have higher average error counts than would normally be expected. The present study indicates that most IPs were not satisfied with the simulator training. Many pointed to the complex switchology, inadequate IP training, and the ineffective computer logic which does not allow simultaneous use of the tactics and mission display panel (Crites, 1977) or simultaneous viewing of the tactics and intercepts displays (Baer & Sanders, 1977). The present IOS design and limited IP training program did not significantly affect training time, but did appear to hinder the full development of quality flight simulator training.

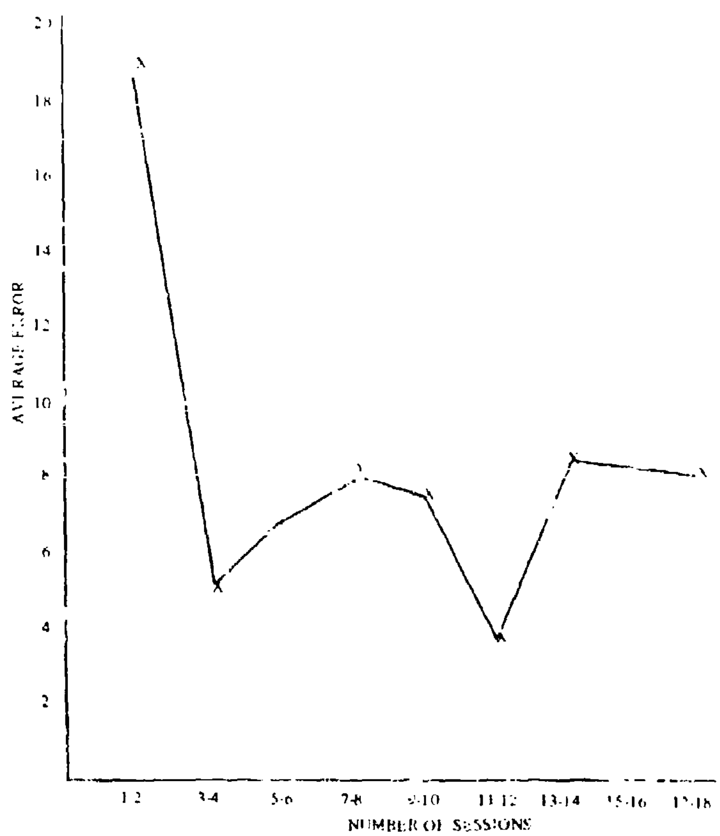

Figure 1. **Number of sessions versus average error count for instructor pilots in 1977 study (r = –.32).**

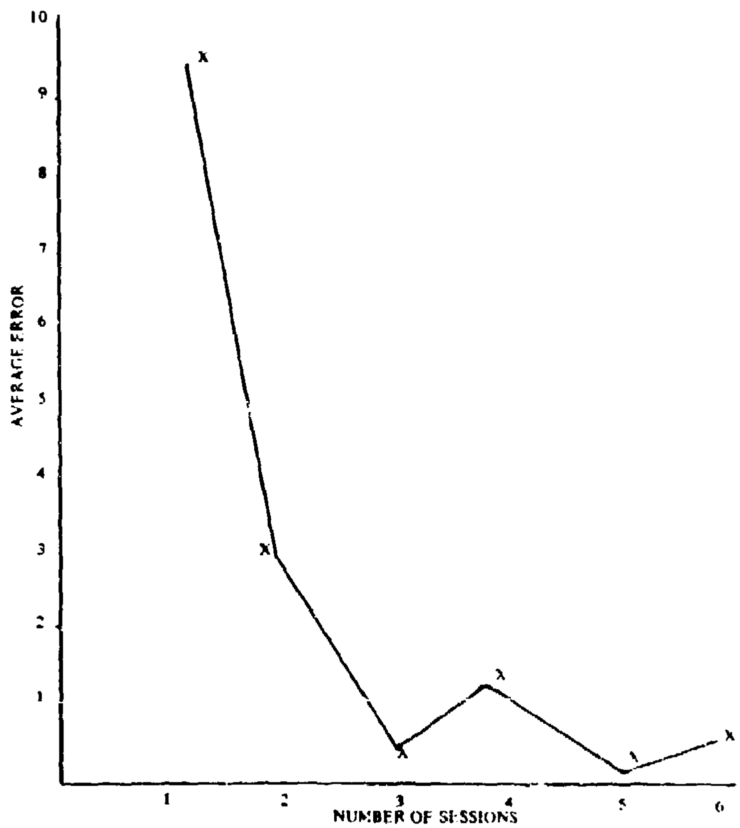

Figure 2. **Number of sessions versus average error count for instructor pilots in 1978 study (r = −.62).**

There must be closer cooperation between simulator designers and operational personnel. The complicated and confounding operating procedures for the F-15A FS IOS which were probably responsible for at least some of the frequent operator errors, attest to the need for early interaction between simulator designers, human factors scientists, and user (operator) personnel at the conceptual, design, and acquisition stages of new training device development. (This recommendation has previously been reported by other investigators.) The designers must solicit and receive feedback from users on the training effectiveness of simulator designs. Open communications at the earliest stages of design may help solve problems such as those pointed out by this report.

Many of the changes to the F-15A FS IOS recommended by the HFT&E (Crites, 1977) and provided to the F-15A FS OT&E manager and other earlier reports during the initial OT&E have recommended considerable improvements be made to the F-15A FS. Even these changes deserve critical review to insure that final configuration will be usable in the operational setting at unit level. These changes must also be cost effective. Such a review follows the theme of this report; that is, the end product (a production flight simulator) should be delivered capable of providing required training while being operated by personnel trained to use the equipment in an effective manner.

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APPENDIX A: SAMPLE IP QUESTIONNAIRE

Name ______________________________ Grade ______ Date __________

SSN ______________________________ Sqdn ________________

FLYING EXPERIENCE:

Aircraft	Total Hours	IP Hours
____________	________	______
____________	________	______
____________	________	______
____________	________	______
____________	________	______

SIMULATOR EXPERIENCE:

Simulator	Total Hours	IP Hours
____________	________	______
____________	________	______
____________	________	______
____________	________	______
____________	________	______

APPENDIX B: SAMPLE SO QUESTIONNAIRE

Name______________________________ Rank ________________ Date ____________

PAFSC ___________ DAFSC _____________ SSN ____________________

EXPERIENCE (In months):

IOS Operator ______________________

Maintenance Technician ____________________

F-15 IOS ____________________

Other IOS:

___________ ___________

___________ ___________

___________ ___________

APPENDIX C: SAMPLE WORKSHEET

F-15 IOS EVALUATION:

Date	Mission Sim No./Course No.	Technician	Inst. Pilot	Student	Completed Yes	Completed No	Comments If ET Used-Set No. Syllabus Deviations	Errors	Sched. Time	Actual Trng Time	Cum. Error Time

APPENDIX D: DATA FOR CALCULATING THE PEARSON PRODUCT MOMENT CORRELATION COEFFICIENT

Present Study		Prior Study	
Average Error	# of Sessions	Average Error	# of Sessions
18	1	36	1
13.33	1	18	1
10	1	13	1
10	1	10	1
6.5	1	7.67	3
6	1	5.08	3
6	1	4.33	3
7.75	1	4.5	4
9	2	7	5
5.6	2	22.57	7
4	2	18.86	7
4	2	6.86	7
3.2	2	1.71	7
2	2	1.71	7
1.5	2	0	7
1	2	8.75	8
1	2	7.56	9
0.5	2	6.89	9
1	3	5.56	9
0	3	11.4	10
2.75	4	5.6	10
2	4	4.09	11
0	4	5	12
0	5	9.23	13
0.5	6	8.47	17
$r = -0.62$, ($p = .00047$)		$r = -0.32$, ($p = .059$)	